Proposal for Broadcast of Heading and Airspeed Information
242A-WP-5-13a
Richard Barhydt, NASA

Purpose of proposal

Provide capability to broadcast heading and airspeed (air reference velocity vector) data to support currently defined and future ADS-B applications.

Summary of Proposed Changes to DO-242:

- Remove references to heading and airspeed data in state vector report (Table 3-5) and modify the accompanying text in Section 3.4.3.1.
- Create a requirement for Class A2 and A3 aircraft to be capable of broadcasting heading and airspeed data.
  - Data reference (magnetic or true heading, indicated or true airspeed) must be available (possible implementation would be "Operational Mode Specific Parameters" of current mode status report).
  - Requirement could be met by new on-condition report delegated for heading and airspeed or through state vector.
  - Requirements for broadcast rate for specific applications are TBD.

Justification

The capability to provide heading and airspeed data is needed to support two currently defined DO-242 applications: Separation Assurance/Sequencing and Flight Path Deconfliction Planning. Both of these applications are available to Class A3 aircraft, whereas only the former is available to Class A2 aircraft. Air reference data is used for conflict detection and prevention when the transmitting aircraft is not being controlled to a defined ground track.

Consider an example where a transmitting aircraft is maintaining a constant heading (heading hold mode) and then commands a turn to a new heading (heading select mode). Flying in these heading reference modes (with no TCP's) is common in today's operational environment. By knowing that aircraft's heading and airspeed (air reference velocity vector) along with the currently provided ground velocity vector, the receiving aircraft can derive the wind encountered by the transmitting aircraft. With wind information, the receiving aircraft can extrapolate the transmitting aircraft's predicted ground track after it completes a turn (when also provided with the commanded heading) or when climbing or descending through a changing wind field. Wind enhancement should improve the performance of conflict detection and prevention routines. The specific flight conditions requiring air reference velocity vector data and the required broadcast rate have not yet been determined. The proposed MASPS revision only requires that A2 and A3 aircraft and the associated ADS-B system be capable of providing this data.

Deriving local wind information through use of the air and ground velocity vectors holds significant promise for other current and future applications. Path prediction

performance by Flight Management Systems (FMS) is strongly influenced by the accuracy of programmed winds aloft data.[1] Studies have shown that atmospheric models augmented with real-time wind information measured by aircraft significantly reduce wind prediction errors.[2] Pilots of current FMS equipped aircraft can program predicted wind conditions into the Control Display Unit (CDU) prior to reaching the top of descent. The FMS uses these predictions along with the descent speed and desired crossing altitude at the bottom of descent waypoint to create an idle thrust descent path. Upon reaching the top of descent, the throttles are retarded to flight idle, and the aircraft descends along the path. If the assumed wind and other pre-programmed conditions are accurate, the aircraft is able to maintain the path at the desired speed. Wind inaccuracy requires the pilot to add speedbrakes or thrust in order to remain on the descent path at the desired speed. Doing so increases crew workload and results in lower fuel efficiency. Future applications will likely require even more precise FMS descent paths. Examples include precision RNP descent paths used for noise abatement and the issuance of required times of arrival at a feeder fix to increase terminal area throughput.

In-trail spacing approaches under consideration at NASA and Mitre also require accurate wind information. One proposed concept attempts to achieve a constant threshold crossing interval for a stream of landing traffic. Prior to reaching the final approach fix, the trailing aircraft is required to maintain a specified time spacing behind the lead aircraft, consistent with safety. Both aircraft fly at the same speed. The time spacing is based on the difference in final approach speeds between the lead and trailing aircraft after passing the final approach fix (when the aircraft is configured for landing) and the current wind conditions. Wind affects the amount of time in which the differences in final approach speeds act to close or stretch the gap between aircraft after passing the final approach fix. For example, a strong headwind would leave more time for a faster trailing aircraft to close the gap between a slower lead aircraft. Inaccurate wind information will lead to greater variability in threshold crossing time, thereby reducing efficiency.

The creation of a new on-condition report that provides heading and airspeed data allows the flexibility to request this data as needed to meet the application. It is suspected that the required broadcast rate would be higher in the terminal area than en-route, although specific requirements have not yet been determined.

References

[1]Williams, D.H. and Green, S.M., "Flight Evaluation of Center-TRACON Automation System Trajectory Prediction Process," NASA/TP-1998-208439, July 1998.
[2]Cole, R.E., et. al, "Wind Prediction Accuracy for Air Traffic Management Decision Support Tools," 3rd SUA/Europe Air Traffic Management R&D Seminar, Napoli, Italy, June 2000.

DO-242A MASPS Revisions

Following is a list of recommended changes to support the above proposal. New text is written in italics and bold text refers to titles of sections or tables.

Proposed Wording for Section 2.1.2.2.2, **Velocity Vector**
Add to end of section, *"The ADS-B system shall provide the capability for defined classes of users to transmit air reference velocity vector information defined below (requirement #)". Required broadcast rate will be determined by the application. This requirement can be met by an on-condition message (Table 3-7(a)) or through the state vector (Table 3-5).*

Proposed Wording for Section 2.1.2.2.2.3, ***Air Reference Velocity Vector***
Knowledge of the transmitting aircraft's air reference velocity vector is necessary for certain separation assurance and flight path deconfliction planning applications. Aircraft are often flown without controlling to a defined ground track (ie. heading hold or select, fly-by, or fly-over turns). In such cases, the aircraft's ground track during or after a turn depends on the wind. Wind information at the location of the transmitting aircraft can be derived when that aircraft's air reference velocity vector is combined with its ground reference velocity vector defined in Section 2.1.2.2.2.1.

Near real-time wind information derived in this manner is also expected to improve performance of in-trail spacing approaches and FMS descent paths and may be required to meet a certain accuracy. (Requirements for specific applications are TBD).

Airspeed information shall be designated as indicated or true (requirement #). Indicated airspeed is defined as the speed indicated on the pilot's airspeed indicator. True airspeed is defined as the speed of the A/V relative to the airmass. Reported airspeed ranges shall be [0-250] knots on the surface and [0-4000] knots airborne (requirement #). Heading information shall be designated as magnetic or true (requirement #). Magnetic or true heading is defined as the angle subtended by the A/V's longitudinal axis and magnetic or true north, respectively. Reported heading range shall be [0-360] degrees (requirement #).

Proposed Wording for Section 2.2.2.3.1, [Separation Assurance and Sequencing] **Environment**
Change sentence in 1st paragraph to, "Each aircraft in Free Flight airspace broadcasts the ADS-B state vector. *Certain classes of aircraft are capable of broadcasting the air reference velocity vector*. Higher capability aircraft equipped with flight management systems may also provide intent information such as current flight path intended and next path intended.

Proposed wording for Section 2.2.2.4.1, [Flight Path Deconfliction Planning] **Environment**
Change sentence to, "The pilots have available state vector identification, and intent information (TCP, TCP+1) concerning proximate aircraft. *Certain applications may also require the air reference velocity vector*.

Table 2-2, **Summary of Information Needs for Applications Supported by ADS-B**
Add new *Air Reference Velocity* section containing the following elements:

Information Element: *Horizontal Air Reference Velocity*
Aid to Visual Acquisition: *n/r*
Conflict Avoidance and Collision Avoidance: *n/r*
Separation Assurance & Sequencing: *R*
Flight Path Deconfliction Planning: *R*
Simultaneous Approaches: *n/r*
Airport Surface (A/V to A/V & A/V to ATS): *n/r*
ATS Surveillance: *R*

Proposed Wording for Section 3.2.3, **Equipage Classifications**
The operational capabilities discussed in Section 2 can be divided into four hierarchical levels (with each level including all capabilities of the preceding level):
Separation Assurance and Sequencing: *air reference velocity vector*, pair-wise assessment with strategic intent information (TCP)
Flight Path De-confliction Planning: *air reference velocity vector*, pair-wise assessment with strategic intent information (TCP, TCP+1)

Proposed Wording for Section 3.2.3.1, **Interactive Aircraft/Vehicle ADS-B Subsystems (Class A)**
Class A2: Supports all class A1 functionality and additionally provides extended range and information processing to support optimized separation applications. This service requires *the ability to broadcast and receive air reference velocity vector* and trajectory change point data (TCP).

Table 3-1**, Subsystem Classes and Their Features**
Class A2 (Comments Column), "Baseline for separation management employing air intent information *and air reference velocity vector**".

Class A3 (Comments Column), "Extends planning horizon for strategic separation employing intent information *and air reference velocity vector**".

Add note: **Capability to broadcast and receive air reference velocity vector should exist even if not used all the time.*

Table 3-3(a), **Interactive Aircraft/Vehicle Equipage Type Operational Capabilities**
Equipage Class and Associated Range: A2
Required Information Broadcast and Receiving Capability, Tx and Rx columns: SV, MS, *OC-1****

Equipage Class and Associated Range: A3
Required Information Broadcast and Receiving Capability, Tx and Rx columns: SV, MS, *OC-2*

Notes: SV = State Vector; MS-P = (Partial) Mode-status w/o TCP; MS = Mode-status w/TCP; OC-1 = On-Condition with air reference velocity vector; OC-2 = On-Condition with TCP+1

****Not needed if air reference velocity vector is included in state vector*

Table 3-4, **ADS-B Report Accuracy, Update Period, and Acquisition Range Requirements**
Remove row 4 of table and replace with the following 2 rows:

On-Condition-1 Acquisition Range (note 8)
Aid to Visual Acquisition: *n/a*
Conflict Avoidance and Collision Avoidance: *n/a*
Separation Assurance and Sequencing: *40 nmi*
Flight Path Deconfliction Planning: *90 nmi (note 3) (120 nmi desired)*
Simultaneous Approach: *n/a*
Airport Surface (note 5): *n/a*

On-Condition-2 Acquisition Range (note 8)
Aid to Visual Acquisition: n/a
Conflict Avoidance and Collision Avoidance: n/a
Separation Assurance and Sequencing: n/a
Flight Path Deconfliction Planning: 90 nmi (note 3) (120 nmi desired*)*
Simultaneous Approach: 10 nmi
Airport Surface (note 5): TBD

Definitions:
On-Condition-1: On-Condition with air reference velocity vector
On-Condition-2: On-Condition with TCP+1

Change Note 8 to: *The delay for MS and OC-2 report updates after a MS or OC-2 state change should be no more than the coast interval associated with the state vector report (with 95% confidence). The delay for OC-1 report updates is determined by the specific application.*

Proposed Wording for Section 3.4.3.1, **State Vector Report**
2nd paragraph, change to: "Other state vector information consists of pressure altitude, altitude rate, *and ground track. Heading and airspeed data are only part of the state vector if not included in an on-condition report (see Section 3.4.3.3). "*
Remove the next sentence, "These elemetns provide backup surveillance in the event of interruption of geometric referenced information, or as a default for participants with limited navigation capabilities."

Table 3-5, **State Vector Report Definition**
Remove row corresponding to Element #13 (Air Speed)
Remove "**(True/Mag Heading)" from row corresponding to Element #14

Proposed Wording for Section 3.4.3.2, **Mode-Status and Partial Mode-Status Reports**
2nd bullet: Operational Mode Specific Parameters. e.g. Speed target, Mag/True Track, *Mag/True Heading,* IAS/TAS.

Proposed Wording for Section 3.4.3.3, **On-Condition (OC) *Reports***
On-condition reports are provided to support future capabilities for specific operations. Data contained in *an* on-condition report will be broadcast when certain conditions are met, when an aircraft is engaging in these operations. *Specific examples of on-condition reports are the Air Reference Velocity Vector and TCP+1 described below.* Appendix M includes specification of on-condition reports for other currently known applications. The ADS-B design should include provision for future expansion using on-condition reports.

As defined in Table 3-3, *equipage classes A2 and A3 support and process* on-condition data.

For each message received containing on-condition information, the on-condition report shall (R3.44) be updated and made available to ADS-B applications. The time of applicability relative to local system time shall (R3.45) be updated with every on-condition report update.

Proposed Wording for Section 3.4.3.3.1, **Air Reference Velocity Vector**
Table 3-7(a) defines the contents of the OC report for air reference velocity vector. The Operational Mode Specific Parameters in the Mode-status report indicate the type of airspeed (indicated or true) and heading (magnetic or true) data being provided. Section 2.1.2.2.2.3 established the operational conditions and information required for air reference velocity vector.

Proposed Wording for Section 3.4.3.3.2, **TCP+1**
Table 3-7(b) defines the contents of the OC report for TCP+1. Section *2.1.2.3.3.2* established the operational conditions and information required for TCP+1.

Table 3-7(a), **Air Reference Velocity Vector On-Condition Report Definition** (new)

Element #	*Contents*
1	*Participant Address (Section 2.1.2.1.2)*
2	*Air Speed* (Indicated/True)*
3	*Heading* (Magnetic/True)*
4	*Time of Applicability (Section 2.1.1.4)*

** Data reference frame is provided in the Mode-status report*

Table 3-7(b), **TCP+1 On-Condition Report Definition**
Use DO-242 Table 3-7, **TCP+1 On-Condition Report Definition**

Table 3-8(a), **Class A Equipment ADS-B Report Contents**
A2 Equipage Class: *add "OC (Note 7)" to all operational capabilites except "Flight Path Deconfliction Planning", which remains "Not Applicable".*

A3 Equipage Class: *add "OC (Note 8)" to all operational capabilites.*

Change Note 3 to: All SV (state vector) entries require elements 1 through *16.*

Add Notes 7 and 8 as follows:
7. Air Reference Velocity Vector On-Condition report elements 1 through 4 required
8. Air Reference Velocity Vector On-Condition report elements 1 through 4 and TCP+1 On-Condition report elements 1-6 required

Table 3-8(b)**, Class A Equipment Broadcast Information Required**
A2 Equipage Class: *add "OC data Note 6a" to all operational capabilities.*
A3 Equipage Class: *add "OC data Note 6b" to all operational capabilities.*

Delete Note 6.
Add Notes 6a and 6b as follows:
6a. Contents to support OC (Air Reference Velocity Vector) elements 1 through 3.
6b. Contents to support OC (Air Reference Velocity Vector) elements 1 through 3 and OC (TCP+1) elements 1 through 5.

Appendix M, **Examples of On-Condition Report Formats**
1st sentence of 1st paragraph: "In addition to the *Air Reference Velocity Vector and TCP+1 on-condition reports* described in Section 3, this appendix provides the definitions for other on-condition report formats."